Ch. 1. Non-Conventional Energy Sources

Introduction: Energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything happens in the world is the expression of flow of energy in one of its forms. Every country draws its energy needs from variety of sources. These can be categorized as commercial or conventional energy sources and non-commercial energy sources or non-conventional energy sources.

The Commercial sources includes the fossil fuels like coal, oil, natural gas, hydroelectric power and nuclear power etc. It is also called as non-renewable energy sources.

The Non-conventional energy sources include wood, animal waste and agricultural wastes. The non-conventional energy sources are vast in nature e.g., Solar energy, wind energy, tidal energy, biogas from biomass etc. It is also called as renewable energy sources.

Non-Conventional Energy Sources:

1. **Biomass:** Biomass is organic material that comes from plants and animals and it is a renewable source of energy. Biomass is produced in nature through photosynthesis achieved by solar energy conversion. In simplest form the reaction is the process of photosynthesis in presence of solar radiation can be represented as follows,

$$H_2O + CO_2 \xrightarrow{solar\ Energy} CH_2O + O_2$$

In this reaction, water and carbon dioxide are converted into organic material i.e. CH_2O, carbohydrates, it breaks at high temperature, releasing an amount of heat equal to 112 Kcal/mol.

$$CH_2O + O_2 \rightarrow CO_2 + H_2O + 112\ Kcal/mol$$

The absorbed energy of photons should be at least equal to this amount. It is possible to produce large amount of carbohydrates by growing under optimum conditions in plastic tubes or in ponds. The algae could be harvested, dried and burned for production of heat that could be converted into electricity by conventional methods. The biomass is used directly by burning or is further proceed to produce more convenient liquid and gaseous fuels.

The Biomass resources fall into three categories;

i). Biomass in its traditional solid mass i.e. wood and agricultural residue. This category is to burn the biomass directly and get energy,

ii). Biomass is in non-traditional form (converted into liquid fuels). In this category the biomass is converted into ethanol and methanol to be used as liquid fuels in engines.

iii). The third category is to ferment the biomass to obtain a gaseous fuel called biogas.

2. **Wind Energy:** Energy of wind can be economically used for generation of electrical energy. Winds are caused from two main factors:
   i) Heating and cooling of the atmosphere which generates convection currents. Heating is caused by absorption of solar energy on earth surface and in the atmosphere.
   ii) The rotation of the earth with respect to the atmosphere and its motion around the sun. The potential of wind energy as a source of power is large. The energy available in the winds over the earth surface is estimated to 1.6×10^7 MW.

   The wind energy which is an indirect source of solar energy conversion can be utilized to run wind mill, which in turn drives a generator to produce electricity. Wind can also be used to provide mechanical power, such as water pumping. In India generally wind speeds obtainable are in the lower ranges. Attempts are on the development of low cost, low speed mills for

irrigation of small and marginal farms for providing drinking water in rural areas. The developments are being mainly concentrated on water pumping wind mills suitable for operation in a wind speed range of 8 to 36 Km per hour.

In India, high wind speeds are obtainable in coastal areas of Saurashtra, Western Rajasthan and some parts of central India. In these areas, there could be possibility of using medium and large sized wind mills for generation of electricity and feeding the same into grid.

Many types of wind mills have been designed and developed. However, only few have been found to be practically suitable and useful. Some of these are: i) multiblade type wind mill, ii) sail type wind mill, iii) Propeller type wind mill, iv) Savonius type wind mill, v) Darrius type wind mill.

The first three are examples of horizontal axis wind mills while the last two have a vertical axis.

3. Tidal Energy: The tides in the sea are the result of the universal gravitational effect of heavenly bodies like sun and moon on the earth. Due to fluidity of water mass, the effect of this force becomes apparent in the motion of water, which shows a periodic rise and fall in levels which is in rhythms with the daily cycle of rising and setting of sun and moon. This periodic rise and fall of water level of sea is called as tide. These tides can be used to produce electrical power which is known ae tidal power. When the water is above the mean sea level, it is called flood tide and when the level is below the mean sea level, it is called ebb tide.

The use of tides for electrical power generation is practical in a few favourably situated sites where the geography of an inlet or bay favours the construction of a large-scale hydroelectric plant. To harness the tides, a dam would be built across the mouth of the bay. It will have large gates in it and also low head

hydraulic reversible turbines are installed in it. A tidal basin is formed, which gets separated from the sea by dam. The difference in water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices turbine respectively. This principle is explained as shown in fig (1).

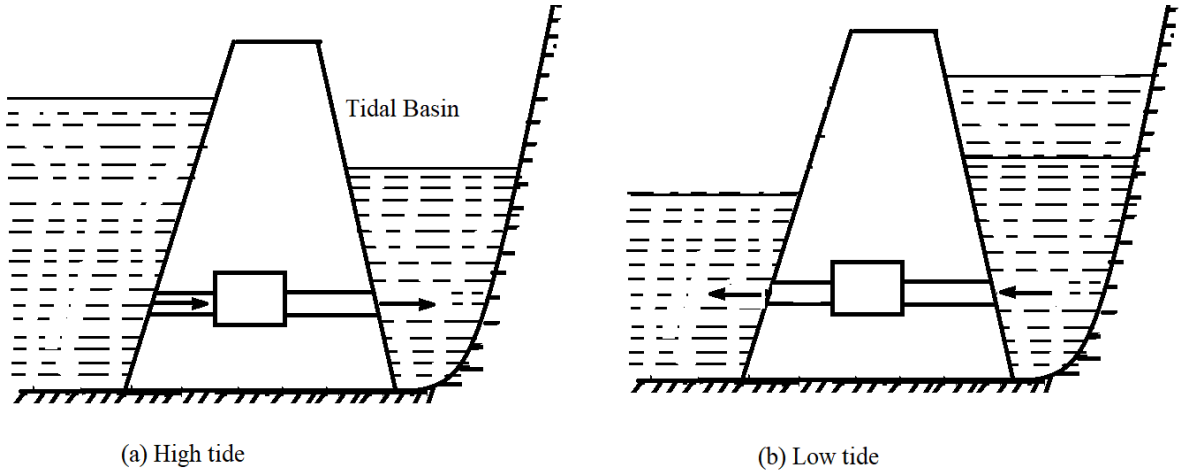

Fig. 1. Principle of tidal power generation

By using reversible water turbines, turbine can be run continuously, both during high tide and low tide. The turbine is coupled to generator, potential energy of water stored in the basin as well as energy during high tide is used to drive the turbine, which is coupled generator, generating electricity.

Above arrangement of harnessing the tidal energy is known as single basin plant. The plant continuous to generate power till the tide reaches, its lowest level. Again, minimum head will be reached when it plays to shut down the turbine and open the bypass valves to drain the remaining basin water to sea. Single basin plant cannot generate power continuously, through it might to do so by using a pumped storage plant, if the load is supplied fluctuates considerably. To overcome this difficulty, two basin plants could be used to generate power continuously without interruption. Such plants can be constructed only in selected places where the height of tide is sufficient to justify economy.

4. **Ocean Energy:** This is also an indirect method of utilizing solar energy. A large amount of solar energy is collected and stored in tropical oceans. The surface of the water acts as the collector for solar heat, while the upper layer of the sea constitutes infinite heat storage reservoir. Thus, the heat contained in the oceans, could be converted into electricity by utilizing the fact that the temperature difference between the warm surface waters of the tropical oceans and colder waters in the depths is about 20-25°K. Utilization of this energy with its associated temperature difference and its conversion into work, form the basis of ocean thermal energy conversion (OTEC) systems. The surface water which is at higher temperature could be used to heat some low boiling organic fluid, the vapours of which would run a heat engine. The exit vapour would be condensed by pumping cold water from the deeper regions. The amount of energy available for ocean thermal power generation is enormous and is replenished continuously. Several such plants are built in France after World War II.

   All the systems for OTEC method work on a closed Rankine cycle and use low boiling organic fluids like ammonia, propane, R-12, R-22 etc. A schematic diagram of Rankine cycle OTEC plant is as shown in Fig. 2.

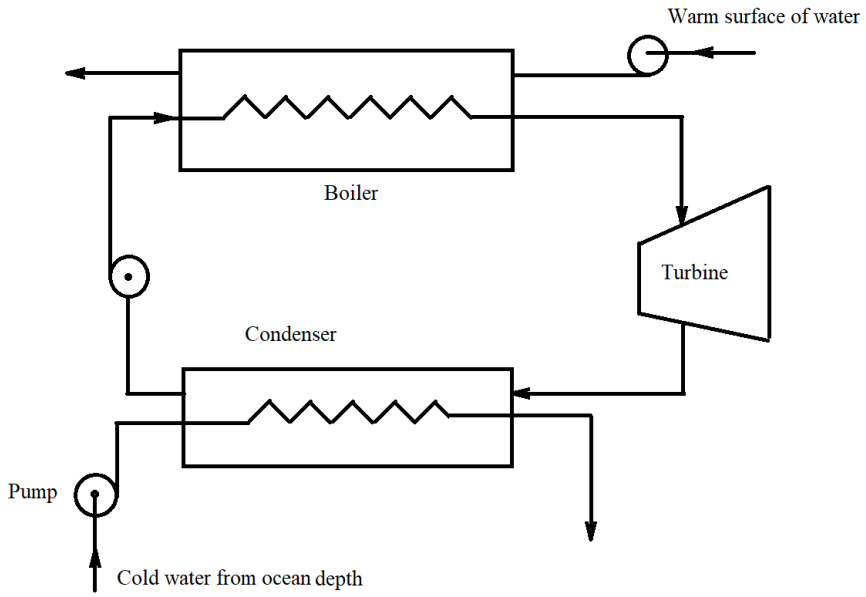

Fig. 2. Schematic diagram of Rankine cycle OTEC plant

The warm surface of water is used for suppling the heat input in boiler, while the cold water brought up from the ocean depths is used for extracting the heat in the condenser.

In India, department of non-conventional energy sources has proposed to install a 1mW OTEC plant in Lakshadweep Island at Kavaratti and Minicoy. The proposed OTEC plant will bring up the water from 1000m depth which has high nutrient value. After providing the cooling effect in the condenser a part of sea water is proposed to be diverted to the lagoons for the development of aqua culture.

5. Geothermal Energy: -

This is an energy which lies embedded within the earth. According to various theories the earth has a molten core. The steam and hot water come naturally to the surface of the earth in some locations of the earth. Two ways of electric power production from geothermal energy has been suggested. In one of these heat energies is transferred to a working fluid which operates the power cycle. This may be particularly useful at places of fresh volcanic activity, where the molten interior mass of earth vents to the surface through fissures and substantially high temperatures, such as between 450 to 550^0C can be found. By embedding coil of pipes and sending water through them can be raised. In the other, the hot geothermal water and steam is used to operates the turbines directly. From the well-head the steam is transmitted by pipe lines up to 1m in diameter over distances up to 3km to power station water separators are usually required to separate moisture and solid particles from steam. A schematic of geothermal power plant as shown in fig. At present only steam coming out of the ground is used to generate electricity, the hot water is discarded because it contains as much as 30% dissolved salts and minerals and there cause serious rust damage to the turbine.

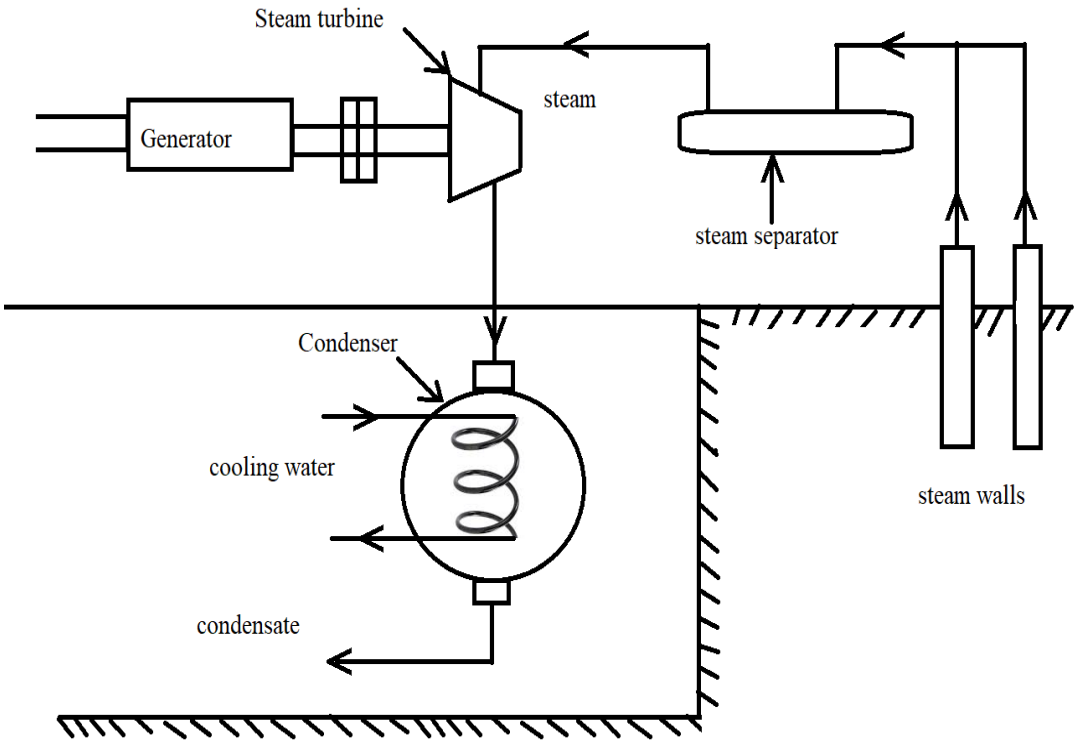

Fig. A schematic of geometheral power plant (wet team)

6. Hydrogen Energy:

Hydrogen is an energy can play an important role as an alternative to conventional fuels provided its technical problems of production, storage and transportation can be resolved satisfactorily and the cost could be brought down to acceptable limits.

One of the most attractive features of hydrogen as an energy carrier is that it can be produced from water which is abundantly available in nature. Hydrogen has the highest energy content per unit of mass any chemical fuel and can be substituted for hydrocarbons in broad range of applications, often with increased combustion efficiency. Its burning process is nonpolluting and it can be used in fuel cells to produce both electricity and useful heat.

7. **Solar Energy:** Solar energy has the greatest potential of all the sources of renewable energy. Energy comes to the earth from the sun. This energy keeps

the temperature of the earth above that in colder space, causes current in the atmosphere and in ocean, causes the water cycle and generate photosynthesis in plants.

The solar power where sun hits atmosphere is 10^{17} Watts, where as the solar power on earth's surface is 10^{16} Watts. The total world-wide power demand of all needs of civilization is 10^{13} Watts. Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is approximately $1Kw/m^2$. Attempts have been made to make use of this energy in raising steam which may be used in driving the prime movers for the purpose of generation of electrical energy. However, on account of large space required uncertainty of availability of energy at constant rate due to clouds, winds, haze etc. there is limited application of this source in the generation of electric power.

Now a days the drawbacks as pointed out that energy cannot be stored and it is a dilute form of energy, since energy can be stored by producing hydrogen, or by storing in other mechanical or electrical devices or it can be stored in containers of chemicals called phase changing salts. These salts which store large quantities of heat in a relatively small volume, melt when they are heated and release heat later as they cool and crystallize.

In analysis commercial energy sources, that world's reserves of coal, oil and gas will be exhausted within a few decades. Nuclear energy involve considerable hazards and nuclear fusion has not yet overcome all the problems of even fundamental research, compared with these technologies, the feasibility of which is still uncertain and contested, the technical utilization of solar energy can prove very useful.

The applications of solar energy which are enjoying most success today are,

i) Heating and cooling of residential building,

ii) Solar water heating

iii) Solar drying of agricultural and animal products,

iv) Solar distillation on a small community scale,

v) Salt production by evaporation of sea water or in land seawaters,

vi) Solar cookers,

vii) Solar engines for water pumping,

viii) Food refrigeration

ix) Solar furnaces

x) Solar photovoltaic cells, which can be used for conversion of solar energy directly into electricity.

8. Bio-Gas:

The main source for production of biogas is wet-cow dung or wet livestock waste to produce biogas. Biogas contains 55 to 65% methane, 30-40% CO_2 and rest impurities i.e. H_2, H_2S and some N_2. The production of biogas is of particular significance for India because of its large cattle population. Some other sources of biogas are-i) sewage, ii) crop residue, iii) vegetable wastes, iv) water hyacinth, v) poultry droppings, vi) pig manures vii) algae etc.

In big cities, sewage source is the main source for production of biogas. Biogas obtained can be used to run pumps to pump out the sewage water itself. Piolet plants for such purpose, capable of handling sewage have already been developed and installed in some areas. The sewage biogas is found to contain 84% methane. Methane could be economically used to run engines to drive electric generators.

In rural sector, biogas finds great applications in cooking, lighting, mechanical power and generation of small electricity. The gas can be used with advantage to improve sanitary conditions and also to check environment pollution. Biogas can be used fully or with diesel in I.C. engines for production of power.

Bio-gas Plant fixed dome type:

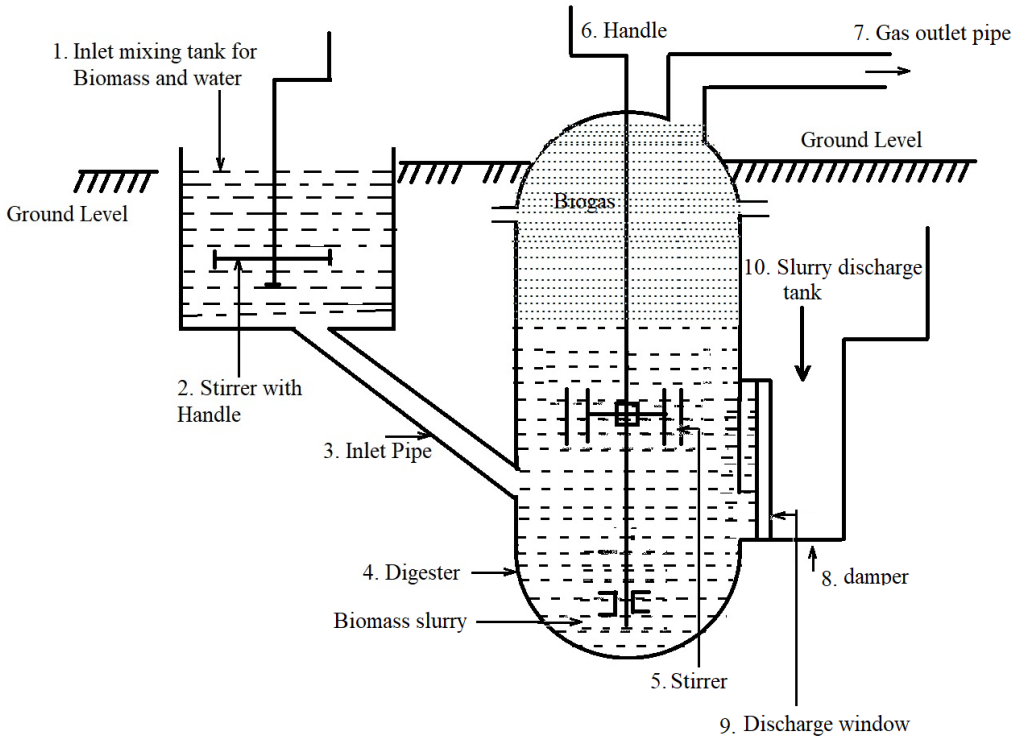

Fig. Schematic diagram of fixed dome type biogas plant

The schematic diagram of the fixed dome type biogas plant as shown in Fig. The inlet tank (1) receives the feed biomass and water or liquid waste. The stirrer (2) with a handle is used for stirring the mixtures to form a slurry. The slurry is fed into digester (4) via inlet pipe (3). The stirrer (5) mixes the slurry in the digester. The biogas generated by anaerobic digestion of the biomass in the digester is collected in the upper half of the digester tank.

The upper dome is fixed type; hence this type of biogas plant is called fixed dome type biogas plant. The biogas is delivered via the gas outlet pipe (7). After the conversion to biogas, the residual spent slurry is discharged by opening damper (8) provided on the discharge window (9).

In this simple fixed dome type biogas plant, there is no provision for expansion of gas in the dome. Hence such plant can be used for small and economic size biogas plant (0.5 to 2 m^3/day). The fixed dome type biogas plant has adopted

on a large scale in China. Hence it is some times called Chinese design. In this plant we have to get, CH_4, CO_2, H_2S

Biogas = CH_4 (60%)+CO_2 (40%) + H_2S

9. Wind Energy:

Wind is an air in motion. Wind energy is a manifestation of solar energy. Energy in the wind is converted into rotary mechanical energy by the wind-turbine. The rotary mechanical energy is used for several applications such as, pumping water, grinding flour, driving generator rotors to produce electrical energy.

Terms and Definitions:

i) **Wind Farm (Wind Energy Park):** A zone containing several wind turbine generator units, electrical and mechanical auxiliaries, substation, control room etc.

Wind farms are located in areas having continuous favourable wind. Such locations are on-shore or off-shore away from cities and forests.

ii) **Wind turbine:** A machine which converts wind power into rotary mechanical power. A wind turbine has aerofoiled blades mounted on the rotor. The wind drives the rotor and produces rotary mechanical energy.

iii) **Vertical axis wind turbine (VAWT):** The blades rotate around a vertical axis.

iv) **Horizontal axis wind turbine (HAWT):** The blades rotate around a horizontal axis.

v) **Propeller (wheel):** Revolving shaft with blades. The blades are set at an angle and twisted.

vi) **Wind mill:** The machinery driven by the wind acting upon sails used chiefly in flat districts for grinding corn, pumping of water etc.

Types of wind turbine-Generator units:

The wind turbines are classified into two general types: horizontal axis and vertical axis.

A horizontal axis machine has its blades rotating on an axis parallel to the ground.

A horizontal axis machine has its blades rotating on an axis perpendicular to the ground.

A wind turbine generator unit consists of the following major subassemblies;

i) A wind turbine with vertical axis or horizontal axis.
ii) Gear chain
iii) An electrical generator
iv) Associated civil works,
v) Electrical and mechanical auxiliaries
vi) Control panels etc.

The wind turbine generator unit converts wind power into electrical power. The propeller type horizontal axis wind turbine has a central shaft with a hub and a propeller. The shaft is mounted on two bearings. The propeller has a few blades with aerofoil design. The wind passes through the propeller and gives a circumferential force and axial thrust.

The torque is responsible for converting wind power to rotatory mechanical power. The mechanical design of the Wind turbine generator unit, nacelle, tower etc, should be strong enough to with stand the axial thrust during worst Winds.

The wind turbine, gears and generator together form a unit. Several identical units are installed in a wind farm.

Horizontal axis wind turbine generator units are manufactured very widely. The three-blade version is the most popular all over the world for unit rating from 15KW to 3MW.

Vertical Axis wind turbine generator units are built commercially by few manufacturers.

Two types of designs are commercially successful

1. Darrius wind turbine with high ϕ configuration.
2. VAWT with H- configuration.

Very large vertical axis Darrius wind turbine with Unity ratings 4MW have been successfully built.

10. Mono-Blade HAWT:

The mono-blade wind turbines have higher rotor and are therefore favourably priced. Smallest mono-blade designs are of 15KW to 30 KW unit rating. This may be used in wind parks or individually for water pumping, battery charging, power supply system for remote installations. Mono-blade wind turbine is as shown in Fig.

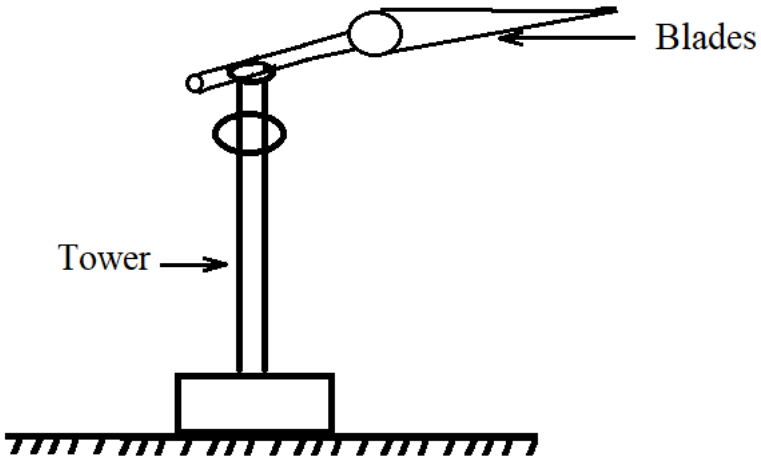

Fig. Mono-blade HAWT

Mono-blade wind turbine can be equipped with synchronous generator or an asynchronous generator. It can be operated as a stand-alone unit or with grid connections. In mono-blade wind turbine blades are generally pitch controlled. The downwind designs are preferred. Wind vanes are used for orientation to the direction of wind.

Due to light weight, installation and dismantling are easy. Blade lengths are in the range of 15m to 25m. Most Heights are in the range of 30m to 60m. Mono-blade design experience minimum stress on the bearing and gears. Designs are aerodynamically optimised with high tip speed /wind speed ratio. Blades are made of metal, glass reinforced plastics, laminated wood, composite Carbon fibre/ fiberglass etc. to obtain light economical and strong design. Service life is of 30 years.

Single blade designs seem to have lesser scope in higher ratings. Two blade and three blade designs are preferred for harnessing more power.

11.Twin blade HAWT generator Units:

Twin blade HAWT units are built in large unit sizes of unit ratings such as 1MW, 2MW and 3MW. Such high-capacity units are installed singly and feed power into the distribution network. Some of the largest wind turbine generator units are twin blade horizontal axis wind turbines as shown in figure.

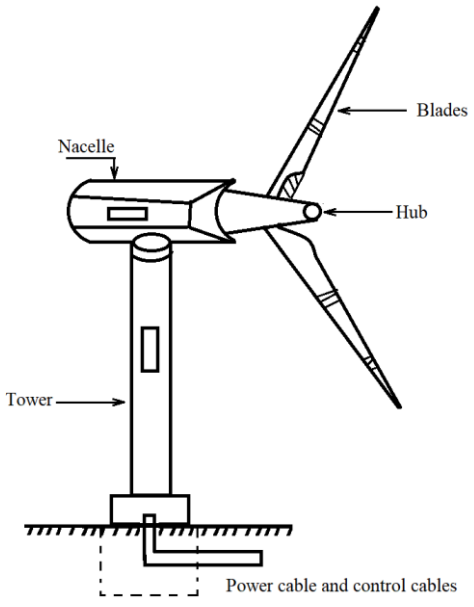

Fig. Twin blade HAWT

Cost of a two-blade turbine is lesser than that of equivalent three blade turbine. Weight of the two-blade rotor is lesser than that of an equivalent three blade turbine. Two blade turbines need tethering control. The wind speed increases with the height. When the rotor is vertical, the blade in the upper position experiences a greater force then the blade in lower position. A pivot within the hub allows the Rotor to lean backward to accommodate extra force. Without such tethering arrangement additional fatigue on the main shaft seriously affects the life of a two-blade wind turbine.

12. Merits and limitation of wind energy:

Merits of wind energy:

i. wind energy is one of the important forms of renewable energy and available free of cost.
ii. This energy is clean and pollution free
iii. Available in many Off-shore, On-shore remote areas, outside cities and forests.
iv. Earth receives vast wind energy, cost effective and reliable wind power generators are being developed.
v. It is help in supplying electric power to remote areas.
vi. It is help in energy conversion of non-renewable sources.
vii. Low operating cost and economically competitive.
viii. Ideal choice for rural and remote areas which lack other energy sources.
ix. Wind energy can be used for obtaining mechanical energy for grinding, pumping etc resulting in energy conservation.

Limitations of wind energy

i. Low energy density.
ii. Favourable winds are available only in a few geographical locations, away from cities, forests.
iii. Variable, unsteady, irregular, intermittent, erratic, sometimes dangerous erratic.
iv. Direction of wind changes and is never constant or regular.
v. Wind turbine design manufacture installation proved to be most complex due to several variables and extreme stresses.
vi. Small units are more reliable but have higher capital cost per KWh. Large units require high technology and have less capital cost per KWh.
vii. Requires energy storage batteries and standby diesel generator for supply of continuous power to load.
viii. Wind farms require flat, vacant land free from forests.

ix. Only in KW and few MW range does not meet the energy needs of large cities and industry.

Multiple Choice Question:

1. Which of the following are non-conventional energy sources?

a) Wind

b) Solar energy

c) Biomass

d) All of these

2. Which of the following is not conventional energy source?

a) Coal

b) Oil

c) fossil fuels

d) tidal energy

3. **Biomass is used in the production of----**

a) fibers

b) chemicals

c) transportation fuels

d) biochemicals

4. Biomass is produced in nature through----- process.

a) Photoelectric

b) Photosynthesis

c) biochemicals

d) None of these

5. The sources of production of bio gas is ----

a) Wet-cow dung

b) wet live stock waste

c) sewage

d) All of these

6. Which of the following is used process to produce biogas from biomass?

a) Anaerobic treatment

b) Aerobic treatment

c) Fermentation

d) Pyrolysis

7. In biogas, the percentage of carbon dioxide is

a) 55-60

b) 35-45

c) 30-40

d) 32-43

8. The main content of biogas is-----

a) methane

b) carbon dioxide

c) nitrogen

d) hydrogen

9. What are used to turn wind energy into electrical energy?

a) Turbine

b) Generators

c) Yaw motor

d) Blades

10. Winds are caused due to----

a) Heating and cooling of the atmosphere

b) The rotation of the earth with respect to the atmosphere

c) The motion of the earth around the sun

d) All of these

11. The tides in the sea are the result of ----

a) the universal gravitational effect of heavenly bodies like sun and moon on the earth.

b) Heating and cooling of the atmosphere.

c) The rotation of the earth with respect to the atmosphere.

d) none of these

12. When the water is above the mean sea level, it is called-----

a) flood tide

b) ebb tide

c) tide

d) tide level

13. What does OTEC stand for?

a) Ocean thermal energy cultivation

b) Ocean thermal energy conversion

c) Ocean techno energy conservation

d) Ocean thermal energy consumption

14. How is OTEC caused?

a) By wind energy

b) By geothermal energy

c) By solar energy

d) By gravitational force

15. Wind energy is harnessed as _____ energy with the help of windmill or turbine.

a) Mechanical

b) Solar

c) Electrical

d) Heat

16. Which type of windmill has better performance?

a) Vertical type wind mills

b) Darrieus type machines

c) Magnus effect rotor

d) Horizontal type windmills

17. Geothermal energy is the thermal energy present

a) On the surface of the earth

b) In the interior of the earth

c) On the surface of the ocean

d) None of the above

18. In dry steam hydrothermal plant, we use

a) Carnot cycle

b) Brayton cycle

c) Rankine Cycle

d) None of the above

19. The solar energy is directly used for-----

a) drying

b) water heating

c) distillation

d) All of the above

20. From the sun the solar energy is radiated in the form of _____ waves.

a) Electromagnetic waves

b) Infra-red waves

c) transverse waves

d) none of the above

21. What are horizontal wind turbines?

a) Wind turbines are rotate about an axis perpendicular to the plane of ground

b) Wind turbines are rotate about an axis diagonal to the plane of ground

c) Wind turbines are rotate about an axis 30 degrees to the plane of ground

d) Wind turbines are rotate about an axis parallel to the plane of wind streamlines

22. What are vertical wind turbines?

a) Wind turbines are rotate about an axis perpendicular to the plane of ground

b) Wind turbines are rotate about an axis diagonal to the plane of ground

c) Wind turbines are rotate about an axis 30 degrees to the plane of ground

d) Wind turbines are rotate about an axis parallel to the plane of wind streamlines

23. Wind turbines are classified as----

a) Vertical axis wind turbine

b) Horizontal axis wind turbine

c) Both a and b

d) None of these

24. Fixed dome type biogas plant consist of ----

a) Inlet tank

b) Dome

c) gas outlet pipe

d) all of these

25. Wind farm is-----

a) a group of wind turbines in the same location used to produce electricity.

b) revolving shaft with blades

c) a machine which converts wind power into mechanical power

d) the machinery driven by the wind

26. The difference in levels of ocean water between a high tide and low tide is called---

a) tidal average

b) tidal range

c) neap tide

d) spring tide

27. Which of the following energy has the greatest potential among all the sources of renewable energy?

a) solar energy

b) wind energy

c) thermal energy

d) Hydro-electrical energy

28. Mono-blade HAWT may be used for---

a) water pumping

b) battery charging

c) power supply system for remote area

d) all of the above

29. The energy radiated by sun on a bright sunny day is approximately

(a) 700 W/m^2

(b) 800 W/m^2

(c) 1 kW/m^2

(d) 2 kW/m^2

30. Limitations of wind energy is----

a) Low energy density.

b) Wind farms require flat, vacant land free from forests.

c) Direction of wind changes and is never constant or regular.

d) All of these